Systematic Innovation Based Design of Energy Efficient House Cooling System

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Abstract—**Energy conservation for buildings is a serious issue for any government and an efficient cooling system of a building in summer is one of major topics for conserving energy. In addition, the resources are very limited in developing countries of tropical regions. The paper deals with the practical approach of enhancing the cooling temperature in the house by the unique problem solving method which is an innovative structured process and sets of practical tools that can be used for the value creation.**

Index Terms—**Energy efficiency, natural cooling, green energy, systematic innovation, low-energy house.**

I. Introduction

The whole world is in an endeavor to cope with the impact of climate change. Climate change, especially global heat is mainly caused by human activities such as massive use of natural resources like coal, oil and gas which are then discharged to the atmosphere resulting to an increase in the temperature of the earth. It is not easy to recognize the effects day by day because it takes a long time. People usually just becomes aware when the disasters happens. Climate change is the global issue that every country is affected. Hence, everyone concerned feels it is necessary to solve the problem.

The energy conserving for buildings is serious issue even government [1-3] and efficient cooling system of a building in summer is one of major topics of energy efficient. In addition, the resources are very limited in developing countries. The paper deals with the practical approach of enhancing the cooling temperature in the house by the unique problem solving method. Systematic Innovation is a structured process and set of practical tools that can be used for the value creation. Because of global warming, the summer season especially in tropical region is now longer and higher in degree of temperature [4]. This makes the life of people more uncomfortable and people find many ways to reduce the heat to at least make them feel better. Air Conditioner (AC) can be one of solutions but installation of ACs in the building occur serious harmful side effects:

- The CFC (Chlorofluorocarbon) in AC is harmful to the ozone layer thereby causing global warming.
- AC consumes more power therefore more negative impact to the environment.
- AC also causes allergenic dangers to people if there is no timely maintenance.
- A poor people does not have money to buy AC neither to pay for electricity bills.

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The initial analysis is shown on Fig. 1. The main reason of this problem is basically the negative impact to environment. The harmful effect of air conditioner is one of main factor of environmental friend house with the energy efficiencies. The unique approaches [5], [6] are applied to solve the issues.

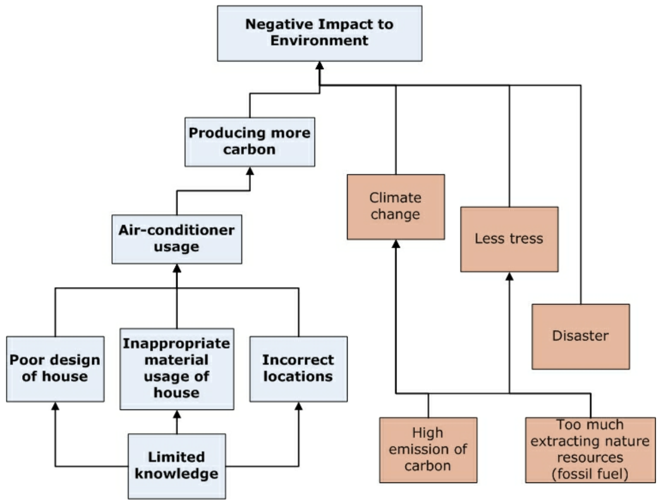

Fig. 1. Analysis of the current cause of cooling system

Systematic innovation [6] is a structured process and set of practical tools can be used to create (or improve) products, process or services that deliver new value to customers. It is also a set of continuous evolving tools that will improve ability to solve the problems. TRIZ [7], [8] is the most powerful methods for systematic innovation methodologies. The substance-field model [7]-[9] and 76 Inventive Standard [5], [10], [11] were conceptualized by the founding father of TRIZ, Genrich Altshuller [1]-[3]. The Standard Solutions are grouped by constraints, so they can help the specialists find appropriate solution concepts [14]. But there are various reasons that the Inventive Standards are not applied widely [15]. Because of the reasons, the special notations so called *Su-Field notations* (aka. *Amang's notations*) are introduced. The notations give intuitive explanations both problems and solutions based on the Inventive Standards. The core for Su-Field model notation is adopted by the queuing model notations also kwon as Kendall-Lee notations. Su-Field notations cover all of the Inventive Standards except for Group 5 which is guidelines for other four groups. Someone who does not even have the full knowledge of the 76 Inventive Standard solutions can understand the problems and candidate solutions intuitively based on Su-Field notations. This notation method is clarifying the Inventive

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Standards simpler ways and users can be guided to the candidate solutions from the problems based on Su-Field model with the minimal knowledge of 76 Inventive Standard solutions [15].

II. Problems of House Cooling System

The research is targeting to design the energy effective way of cooling inside of houses (or buildings). Green (i.e., eco-friendly) solutions are always welcome and encouraged by the government and many international organizations who work for environment and/or climate change fields. Based on this problem, there are brief guidelines of solutions how to design a natural cooling system that:

- Help people install the auto cooling system that maximizes the use of natural resources and contribute to solve problem of climate change.
- Help people to enjoy the fresh, healthy air at a minimized cost.
- Apply poor friendly and eco-friendly technologies.
- Easy to install and maintenance.

To analyze the problem more clearly, Function Analysis and Root Cause Analysis (RCA) are applied. Based on the formulating the problem, the problem can be defined as follow:

Problems:

Element: Air (in the house)
Name of Feature: Temperature
Value: Hot (>a)

The final goal is that the air in a house cool enough to stay without any additional resources included in an air conditioner. At the beginning, the problem is about cooling house but it actually about cooling "air" in the house. The next step applies the problem into Function Model (see the Fig. 2).

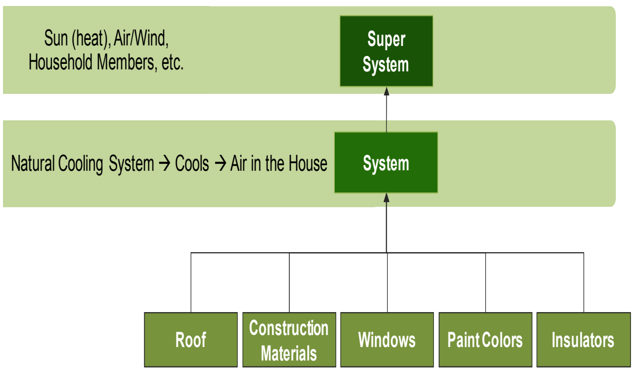

Fig. 2. Function model of cooling house

From the function model, the elements (i.e., sub-system) of the system (home) are as followed Table I:

TABLE I: Elements of the Function

Sub-system	Function
Roof	Protection
Wall	Enclosure
Window	Opening
Insulator	Insulation
Paint	Color (aesthetics), material protection

III. Concept Solution Design by Using Systematic Innovations

A. Enhanced Su-Field Model Summary

The innovative notation based on Su-Field model (Su-Field notation) is applied [15] and innovative notation schema is classified the Inventive Standards more simple way and users can be guided to the candidate solutions from the problems based on Su-Field model [5, 10, 11] with the minimal knowledge of 76 Inventive Standard solutions. Su-Field Notation is defined as follow:

$$(a/b/c):(d/e/f) \tag{1}$$

where the symbols *a, b, c, d, e* and *f* stand for basic elements of the model as follows:

a = arrivals distribution,
b = service time distribution,
c = number of servers (c=1, 2, 3, …)
d = service properties (i.e., FCFS, LCFS, SIRO)
e = capacity of the system
(a waiting room and servers)
f = population of input resources.

The attributes for fields and substances indicate how to modify the substances and the fields. Su-Field Notation provides a user to be guided even with minimal knowledge of Theory of Inventive Problem Solving (TRIZ) method [16]. The problem solvers can adopt the candidate solutions based on the notations without the full knowledge of 76 Inventive Standard solutions in TRIZ.

B. Problem Clarifications

The problem for removing of heating can be described as Su-Field Model. Object (S_1) is the air inside of the house which directly affects the temperature of the house. Since the roof is directly acting the air in the house, Tool (S_2) is the roof of house. Based on Su-Field Model, Problem Type-2 [15] as the Su-Field Notation is the problem that contains the harmful action and the candidate solution is basically removing the harmful function:

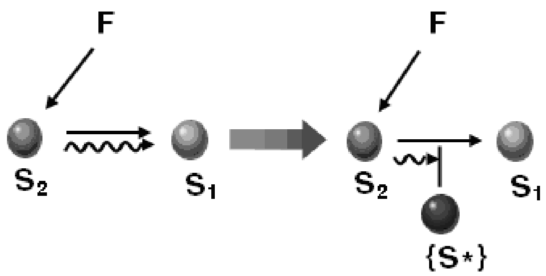

Fig. 3. Candidate solution of problem type-2

From Fig. 3, the candidate solution of Problem Type-2 can be determined as follow [15]:

$$2/S/F\{/0\} \rightarrow \begin{cases} 2/S^*/F, & S^* = S^+ \text{ or } S' \\ 2/S/F,^+ & \\ 2/S/F/a, & 0 < a < 1 \end{cases} \tag{2}$$

where S^* and F^* are the optimal attributes of the substances and the fields to solve the problem. The typical solution is

$$2/S/F\{/0\} \rightarrow 2/S''/F\,.$$

It means that one of substance (typically, Tool is first target to modify) is changed somehow to remove the harmful effect (i.e., heating air in the house).

IV. Concept Design for Cooling Air

Based on the concept solution, changing the material and/or colors of the roof are the solutions for removing harmful effect of the system. It can be observed that certain building materials have higher absorption rate of heat and sunlight (see Table II). It increases the overall temperature inside the house. Therefore, one of the recommendation is the roofs that polished copper (18% absorption) or white asbestos cement (42%). Thatched roof would make the house more airy if applicable in the house's setting. For the walls, white plaster (7%) or white marble (44%) would be better options than brick or concrete [2].

TABLE II: Energy Efficiency of Materials

BUILDING MATERIAL	Absorption (%)
Brick (common)	
Light Red	55
Red	68
Marble	
White	44
Dark	66
Polished	50 – 60
Metals	
Steel	45 – 81
Galvanized iron, new	64
Galvanized iron, dirty	92
Copper, polished	18
Copper, tarnished	64
Lead sheet, old	79
Zinc, polished	46
Paints	
White emulsion	12 – 20
White paint, 4.3 mm on aluminum	20
White enamel on iron	25 -45
Aluminum oil base paint	45
Gray paint	75
Red oil base paint	74
Black gloss paint	90
Green oil base paint	50
Black paint, 4.3 mm on aluminum	94 – 98
Roofing Materials	
Asbestos cement, white	42
Asbestos cement, 6 months exposure	61
Asbestos cement, 12 months exposure	71
Asbestos cement, 6 years exposure	83
Asbestos cement, red	69
Tile clay, red	64
Tile	65 - 91
Miscellaneous	
Aluminum, polished	15
Concrete	60
Concrete, rough	60
Plaster, white wall	7
Wood	60
Asbestos cement board, white	59
Aluminum foil	15
Ground Cover	
Asphalt pavement	93
Grass, green after rain	67
Grass, high and dry	67 – 69
Sand, dry	82
Sand, wet	91
Sand, white powdered	45
Water	94
Vegetable fields and shrubs, wilted	70
Common vegetable fields and shrubs	72 – 76
Ground, dry and plowed	75 – 80
Bare moist ground	90

Roofs are the first contact of sunlight and dark-colored roofs absorb more heat. As evidence to this, the infrared analysis below shows that black captures the most heat and sunlight. Opt for white (or light colors) instead which is about 20 degrees cooler compared to black. This reduces the overall cooling load of the house (see Fig. 4).

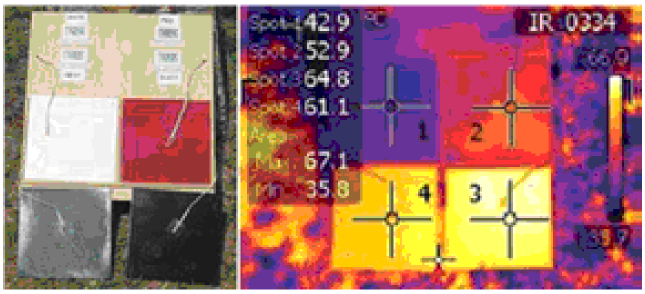

Fig. 4. Temperature differences within colors

Redesigning the shape of the roof is the alternative solution under the same concept solution (i.e., modify the roof). Ventilation techniques are helpful in letting the house breathe (see Fig.5).

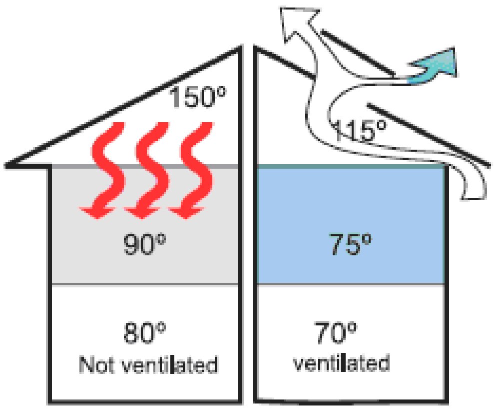

Fig. 5. Temperature differences by shape changes

Hot air moves up by convection (stack effect) and trapped air causes molds when moisture is created due to condensation. Vents could avert this. They must ideally be installed at opposite sides of the roof eaves (or soffits) to allow cross ventilation.

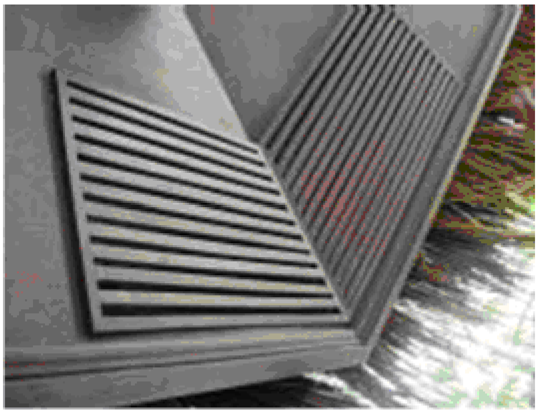

Fig. 6. Actual design of roof shape (inside of house)

V. CONCLUSIONS

The problems in this research can be compromised without the use of sophisticated and expensive materials in order to improve and enhance the characteristic of certain equipment which has always been a part of our everyday lives. The major target of the project is developing the energy efficient way for cooling house. The new approach of Systematic Innovation method is applied for solving problems for developing new design. Even though the research is dedicated with environment and civil industries, the pattern of Systematic Innovation approach can be also applied to other industries.

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